

Uncertainty Related to Geophysical Sampling

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LONG TERM GOALS

The goals of this research are to define and characterize the variabilities and uncertainties in the components and linkages of the general physical-geo-acoustical system (the System) relevant to the support of naval operations, and transfer quantitatively the spatial-temporal environmental variabilities and uncertainties through the System, including coupled interactions, in order to determine uncertainty measures, sensitivities and feedback's critical for operational predictions and parameters.

OBJECTIVES

Transfer uncertainties from the acoustic environment to the sonar and its signal processing, in order to effectively characterize sonar performance and predictions. Construct, calibrate and evaluate uncertainty and variability models, for the System and its components, to address forward and backward transfer of uncertainties based upon the process of end-to-end data assimilation. Develop generic methods for efficiently and simply characterizing, parameterizing, and prioritizing System variabilities and uncertainties arising from regional scales and processes.

APPROACH

The nature of the horizontal and vertical distribution of the bottom and sub-bottom scales and attributes (attenuation, velocity, density) will also be evaluated using acoustic data, ancillary data (including but not limited to in situ samples, seismic) and stochastic models relating the variable of the various components to observable features. The uncertainty in acoustic prediction will be initially viewed in terms of the mean error in acoustic prediction caused by the using the *i*th geoacoustic model as the input geoacoustic model in each of the other source sites. The variations in geoacoustic models will be correlated with the variations in ancillary data to determine the degree to which surface observables can be used to cue sampling strategies.

The areal variation in scattering strength will be investigated by inverting for scattering strength at each of a number of source locations. From the inversion for geoacoustic parameters we will have an estimate of the source beam pattern, and a geoacoustic model. Using these as input we can invert for bottom scattering strength as a function of grazing angle, and as function of location. We can then estimate the uncertainty in reverberation prediction (a system function) in the exercise area.

The resulting statistical parameters will be used to quantify sonar processing performance (signal and reverberation). The System Probability Density Function (PDF), a probabilistic description of the

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environment's intrinsic variability, measurement uncertainty, and impact on the sonar's signal-to-interference ratio, will be developed for fleet applications. These PDFs will be assessed as to their impact on signal processing, including detection and estimation (bearing, range, depth, etc.).

The combination of pdf's will then indicate used to indicate a sampling strategy that optimizes the amount of collected data needed to characterize an area.

WORK COMPLETED

The surficial geology, and shallow subsurface geology of the ACT III site A for acoustic were determined from a combination of in situ measurements, and published material. From the geology and geophysics data we constructed base geoacoustic models to use as both starting fields for inversion processes, and zeroth order comparison.

ADCP bathymetry data were merged with DBDB-V to construct a base bathymetry for the exercise. Since each leg of the exercise took place in a compact zone spatially and temporally the sound speed field for the data was derived from the nearest measurement.

We inverted TL data for geoacoustic environment from CW sources at 5 frequencies (47, 83, 111, 354, 604) using a simulated annealing method with FEPE as the propagator. The inversion was done simultaneously at all frequencies to insure that 'best solution' to all frequencies. Time series (50 Hz to 800 Hz) for single hydrophones were inverted for geoacoustic environment using small omni-directional sus charges as sources by synthesizing the time series using FEPE, and by calculating the time series via the method of Gaussian packets. For the inversion using CW sources at criterion of average absolute error of 3 dB was used, while for the time series a similar a multiplicative factor of two for the average absolute error was used although the errors are not strictly comparable. The geoacoustic inversion repeated using the observed variation in the sound speed profile during the exercise. Inversions based Biot modeling using limited chirp sonar data was used as an independent verification of the inversions of explosives, and cw sources using simulated annealing.

Bottom scattering strength for number of events was inverted from small omni directional SUS charges located within 10 km of the bottom mounted receiver. The scattering strength inversions were based on the mean geoacoustic profile derived from the geoacoustic inversions. In the scattering inversions the low angle scattering data was better represented than the high angle scattering data, thus the results are for mostly low angle scattering.

The inverted bottom parameters were then used to construct signal excess versus range for the range of geoacoustic variability encountered in the area with the scattering strength model derived from the mean geoacoustic model.

RESULTS

The results of the geoacoustic inversion models are consistent among themselves, that is the predictions using the geoacoustic models in FEPE for the CW sources agree to less than 2 dB average absolute mean error. Analysis of the geoacoustic models and surface sedimentary geology (KORDI) personal communication, and revealed areas of both strong and weak correlation between the surficial material. The strong areas of correlation occur in areas dominated by relic materials from the Pleistocene period; while weaker correlations occur where modern fine grain sediments overlay the

relic material. Echo sounding data, grab samples, and cores all suggest that modern veneer is negligible in agreement with the geoacoustic inversions. Application of the bottom inversions yielded

- The inversion of cw and sus charges showed no significant difference in suggested geoacoustics or underlying geologic structure. They were consistent with a two layer shallow structure consisting of a sand-like layer overlying a faster substrate.
- Analysis of the Biot results yielded a critical dependence on tortuosity. As tortuosity decreases (the path length between two adjacent points along a stream line increases) the velocity differential between low and high frequency decreases, and the limit of low tortuosity the porous media acts as a non permeable visco-elastic media. This results was somewhat surprising since tortuosity was expected (at least in some literature) to control attenuation

The scattering strength results indicate little variation in scattering strength (if the bottom topography is modeled carefully). Application of the scattering strengths obtained for the bottom, along with the bottom loss models inverted from the data yielded:

- signal to noise ratio in the reverberation limited areas showed little variation in strength (0.6 dB mean, 0.4 dB standard variation)
- noise limited signal to noise variation was much higher (3.4 dB mean, 2.5 dB standard deviation)
- the range at which detection became noise limited varied approximately 20 % over the range of geoacoustic inverses, and scattering strengths inversions. The variation in maximum detection range correlated with the noise limited range.
- variation in measured sound speed structure had little impact on the inverted geoacoustic bottoms. This was largely the result of little difference between the maximum grazing angle for low bottom interaction (less than 1 dB per bounce) among the measured profiles.

IMPACT/APPLICATIONS

For a fixed receiver system in a littoral siting the variation in mean geoacoustic environment appears to limited to at most a dB for an active system. Defining the mean environment of the location, which may consist of mulitple sub environments, would therefore limit the system uncertainty that can be attributed to geology. Thus for a high interest area, a mean environment would represent a high payoff investment.

RELATED PROJECTS

Geoacoustic Inversion Techniques

PUBLICATIONS

J.K. Fulford "Effects of Dispersive Porous Media Flow On Biot Model Predictions", submitted to Journal "Mathmatics and Computers in simulation"